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GLASS TOUCH PANEL WITH ADHESIVE HAVING HYGROSCOPIC FINE PARTICLES

FIELD OF THE INVENTION

[0001] The present invention relates to a glass touch panel, and more particularly, to a novel glass touch panel of a glass/glass type which is ~~extremely~~ excellent in terms of high temperature and high humidity ~~proof~~ resistance, and also has ~~a~~ merit of a narrow frame, and thus is useful for various kinds of displays such as a car navigation display, a video camera display and a monitoring display.

BACKGROUND OF THE INVENTION

[0002] There has often been used a touch panel for various kinds of displays such as a CRT display. The touch panel is capable of inputting information by using a fingertip or a pen.

[0003] ~~The~~ A basic structure of the touch panel has a glass substrate, a transparent resin substrate above the glass substrate, and conductive films on ~~the~~ surfaces of the glass substrate and the transparent resin substrate opposing each other. Also, spacers are optionally used between the glass substrate and the resin substrate.

[0004] However, the touch panel having such basic structure has been not always been satisfactory in terms of durability, environment ~~proof~~ resistance and wear ~~proof~~ resistance. Further, clearness of ~~the~~ a screen has not been satisfactory, ~~one~~ and aging discoloration of the screen has been remarkable.

[0005] In view of these ~~problem~~ problems, there has been invented a glass touch panel (refer to JP1997-146707) capable of realizing excellent durability, environment ~~proof~~ resistance and wear ~~proof~~ resistance, and also a beautiful screen ~~and~~ exhibiting less discoloration and color shading. As ~~show~~ shown in Fig.1, ~~the~~ this glass touch panel has a pair of transparent substrates 1a,1b, each

having transparent conductive films 2a,2b, ~~and~~ opposed to each other, at surfaces of the transparent ~~conductive film surfaces~~ substrates, wherein ~~the~~ upper transparent substrate 1a, as a touch input portion, is a glass substrate as ~~well as the~~ is lower transparent substrate 1b. ~~It~~ The glass touch panel also has ~~an extending~~ extended wiring 4, a bonding ~~means~~ member 5 and a silver electrode 7.

[0006] However, this prior art glass touch panel, having such distinctive features, still needs to be improved much more in terms of temperature and humidity ~~proof~~ resistance in order to meet ~~the~~ severe demands of various industries relating to displays. For example, as a display of a navigation system for automobiles and such, high temperature and high humidity ~~proof~~ resistance is required as much as possible.

SUMMARY OF THE INVENTION

[0007] In view of the above, it is ~~the~~ a main object of the present invention to provide a novel glass touch panel having ~~excellent~~ beneficial features such as excellent durability, environment ~~proof~~ resistance and wear ~~proof~~ resistance, a beautiful screen ~~and~~ exhibiting less discoloration and color shading, as well as having ~~extremely~~ excellent high temperature and high humidity ~~proof~~ resistance as compared with the prior art glass touch panel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The foregoing and other objects, features and advantages of the present invention will be better understood from the following detailed description, taken in conjunction with the accompanying drawings, in which:

[0009] Fig. 1 is a cross-sectional view showing ~~the~~ a prior art glass touch panel.

[0010] Fig. 2 is a cross-sectional view showing one example of ~~the~~ a glass

touch panel of the present invention.

[0011] Fig. 3 is a cross-sectional view showing another example of the glass touch panel of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[Adhesive blended with hygroscopic fine particles]

[0012] ~~The~~ A glass touch panel of the present invention is a touch panel of a glass/glass type and is different from ~~the~~ a conventional glass touch panel in a manner of bonding of ~~the~~ upper transparent glass substrate 1a and ~~the~~ lower transparent glass substrate 1b as shown in Figs. 2 and 3.

[0013] As shown in ~~Fig.~~ Figs. 2 and 3, the glass touch panel of the present invention has ~~the~~ upper transparent glass substrate 1a and ~~the~~ lower transparent glass substrate 1b, each having ~~the~~ a respective transparent conductive ~~films~~ film 2a, 2b, and being opposed to each other. The glass touch panel ~~of~~ as shown in Fig. 3 also has ~~superfine~~ superfine particle dot spacers 3 on the transparent conductive film 2b of the lower transparent glass substrate 1b. The transparent conductive films 2a, 2b may be disposed in a ~~suitable shape~~suitably shaped pattern.

[0014] Then, in the present invention, the upper transparent glass substrate 1a and the lower transparent glass substrate 1b are bonded and secured to each other by ~~the~~ use of an adhesive 6 mixed with hygroscopic fine particles, which are fine particles having hygroscopicity.

[0015] Therefore, since the hygroscopic fine particles in the adhesive 6 absorb ~~humidity~~ moisture effectively, a humidity ~~proof~~ resistant property much ~~more excellent~~better than that of the conventional panel can be attained even in an extremely high temperature condition. As has already been ~~already~~ described, a ~~the~~ high temperature and high humidity ~~proof~~ resistant property is extremely important ~~in~~ for ~~the~~ use ~~of~~in a highly ~~humidity~~ humid condition, and therefore, the glass touch panel of this invention can be used more preferably for

a display ~~and such~~ of a navigation system ~~in the~~ inside of an automobile, and ~~such~~ the like, for example.

[0016] The hygroscopic fine particles must exhibit full hygroscopic ~~feature~~ features even in the adhesive 6. For example, fine silica-type particles having hygroscopic ~~property~~ properties can be used preferably as such particles. ~~The~~ A size of the hygroscopic fine particles should not be limited in any way as long as they ~~realize~~ exhibit high temperature and high humidity ~~proof~~ resistant properties while ~~maintaining~~ adhesiveness of the adhesive 6 is maintained. However, from a viewpoint of ~~the~~ realization of still more effective ~~coexistence~~ co-existence of adhesiveness and high temperature and high humidity ~~proof~~resistance, for example, a diameter of at most 50μm ~~or less~~ is preferable, a diameter of 5 to 50μm is more preferable, and further a diameter of 5 to 10μm is much more preferable. As for ~~the~~ a mixing amount, although there is naturally a ~~relation~~ relationship with ~~the~~ diameter ~~size~~, it should not be limited in any way as long as the particles ~~realize~~ exhibit high temperature and high humidity ~~proof~~resistant ~~property~~ properties and ~~maintain~~ allow an adhesive property of the adhesive 6 to be maintained at the same time. However, for still more effective ~~coexistence~~ co-existence of ~~the~~ both properties, it is preferable to mix the particles with a weight ratio of at most 10%, ~~or less~~ and more preferable with a weight ratio of at most 5% ~~or less~~.

[Silver Electrode blended with glass fiber]

[0017] As shown in Figs 2 and 3, in the glass touch panel of this invention, it is also preferable to use a silver electrode 7 mixed with a glass fiber. The silver electrode 7 is disposed at a predetermined position of ~~the~~ an outer periphery of the upper transparent conductive film 2a and the lower transparent conductive film 2b.

[0018] This silver electrode 7 mixed with a glass fiber can maintain ~~the~~ a gap between the upper transparent conductive film 2a and the lower transparent

conductive film 2b very ~~much~~ reliably, thereby realizing ~~extremely~~ excellent smoothness ~~and~~ while also preventing screen distortion and unevenness ~~in~~of ~~the~~ image quality, as well as ~~and also~~ interference ~~infringes~~ infringement, much more effectively than does the conventional glass touch panel.

[0019] From ~~the~~ a viewpoint of realizing sill more effective smoothness, it is preferable to mix the glass fiber into the silver electrode 7 with a weight ratio of at most 10%, ~~or less~~ and also to use a silver paste having ~~a~~ an electric resistivity of at most 5.0×10^{-4} Ωcm ~~or less~~ for the silver electrode 7.

[Performance and Characteristics of Glass Touch Panel]

[0020] Additionally, the glass tough panel of the present invention as described above should have the following required performance and characteristics. Of course, the glass touch panel of the invention can easily achieve such high performance and characteristics.

[0021] Among all, ~~the~~ light transmittance should be extremely favorable. That is, ~~the~~ a light transmittance of at least 85% ~~or more~~ is preferable and 90% is more preferable. Such high transmittance can provide a beautiful screen.

[0022] Next, ~~the~~ an operation temperature should preferably be −30 to 65°C under ~~the~~ a condition of at most 90%RH, ~~or lower~~ and ~~the~~ a preservation temperature ~~on~~ of the condition with no dewing should preferably be −40 to 85°C (12 hours) under ~~the~~ a condition of 95%RH. Further, as for ~~the~~ humidity ~~proof (humidity resistance)~~resistance, the glass touch panel should attain 1000 hours of use under ~~the~~ a condition of 60°C, ~~95%~~95%RH. Furthermore, the glass touch panel should ~~attain~~maintain ~~the~~ heat resistance at 85°C and ~~the~~ cold resistance at −30°C.

[0023] As for ~~the~~ mechanical characteristics, the glass touch panel should generally have ~~the~~ an operation load of 10 to 200 g when ~~the~~ a switch ~~becomes~~ ~~a~~enters into a conduction state by pressing the upper transparent glass substrate 1a with a test rod having its top end ~~R~~ having a radius of curvature of 4 mm,

diameter of 8 mmφ and hardness of 60°. ~~The~~ A surface hardness should be 5 to 7 Mohs hardness.

[0024] Referring to ~~the~~ a heat cycle as ~~the~~ a durability index, the glass touch panel should operate over 200 cycles, one cycle comprising consecutive procedures of leaving it for ~~1~~ one hour in an atmosphere of −30°C and then leaving it for ~~0.5~~one half hour at a room temperature (or normal temperature), ~~and~~ further leaving it for one hour in an atmosphere of +85°C, and then leaving it for ~~0.5~~one half hour at a room temperature (or normal temperature).

[0025] In addition, an inactivation gas or air may be injected just before sealing in order to prevent occurrence of interference fringes as well as to smooth ~~the~~ recovery of glass (so called bounce) after input. Further, ~~the~~ an operation load may be controlled by measuring it with a tension gauge in order to ~~suit~~ make sure it is suited for various purposes. In this case, for example, it is preferable to make the bounce at most 10 msec ~~or less~~ for an ordinary ~~operation~~ operational method ~~with~~ using a finger.

[0026] From a viewpoint of ~~the~~ material for the panel, borosilicate glass or soda glass having a thickness of from 0.15 mm to 0.3 mm may ~~be~~ preferably be used for the upper transparent glass substrate 1a. And, for example, ~~the~~ upper transparent glass substrate 1a ~~by~~ of borosilicate glass may preferably have physical properties as in the following Table 1.

Table 1 [Physical properties of the upper glass substrate]	
Heat expansion coefficient (0 to 300°C)	70 to 80 × 10^{-7}/°C
Young's modulus	7 to 8 × 10^3 kg/mm^2
Poison ratio	0.20 to 0.24
Knoop hardness	590 to 615 KHN_{100}
Density	2.30 to 2.85
Distortion point	480 to 520°C
Gradual cooling point	520 to 580°C
Softening point	700 to 750°C
Volume resistivity	8 to 10 log ρΩ cm

Dielectric characteristic (1 Mhz, at 20°C) Dielectric constant Loss	 6 to 8 0.2 to 0.6
Refractive index	1.5 to 1.54

[0027] Commercial products can be used for such glass having the above properties.

[0028] As for the lower transparent glass substrate 1b, soda glass having a thickness of from 0.5 mm to 3.0 mm may preferably be ~~preferably~~ used.

[0029] Further, as for the transparent conductive films 2a, 2b disposed ~~to~~ on such glasses 1a, 1b, thin films of ITO, tin oxide and ~~such~~ the like, especially, those formed by sputtering and chemical vapor deposition (CVD) may ~~be~~ preferably be used. ITO may also be vapor-deposited on a deposition of SiO_2 and ~~such~~ the like. This vapor deposition is a preferred method with regard to ~~the~~ an adhesion property and ~~uniformness~~ uniformity property of the film.

[0030] In ~~the~~ a case where the superfine particle dot spacers 3 are disposed as shown in Fig. 3, it is preferable to use a spacer formed ~~by~~ from a thermosetting resin and having a diameter of from 20 to 100 µm, a height ~~(=~~(i.e. dot thickness) of from 3 to 6 µm, and an inter-dot pitch of from 2 to 4 mm.

[0031] Electrical properties ~~as~~ of a touch panel may preferably be as shown in the following Table 2.

Table 2 [Electrical properties of the glass touch panel]	
Rating	DC 5V, 50 mA or less
Insulation resistance	DC 25V, 10 MΩ or more (between upper and lower electrodes)
Linearity	± 3.5% or less
Bounce	10 msec or less (by ordinary finger operation)
Antistatic voltage withstanding	15 kV or higher
Dynamic range	Lower limit: 0 to 0.7V, Upper limit: 5 to 4.6 V

[Method of manufacturing the glass touch panel]

[0032] Hereinafter, a method for manufacturing the glass touch panel of this invention will be explained. For example, the glass touch panel of Fig. 3 can be manufactured according to ~~the~~ steps [1] to [6] described below.

[0033] Step 1. Formation of transparent conductive films 2a, 2b of ITO ~~and such~~ onto transparent glass substrates 1a, 1b by performing sputtering and CVD.

[0034] Step 2. Patterning of the transparent conductive films 2a, 2b by performing resist ink printing, film etching and resist ink peeling, or by performing photo-lithography.

[0035] Step 3. Formation of ~~superfine~~ super-fine particle dot ~~spacer~~ spacers 3 by performing resist ink printing and thermosetting, or by performing photo-lithography.

[0036] Step 4. Formation of silver electrode 7 by performing glass ~~grass~~ fiber mixing, silver paste printing and baking.

[0037] Step 5. Printing of adhesive 6 by performing hygroscopic fine particles mixing, ~~and~~ printing and temporal baking, or by performing photo-lithography.

[0038] Step 6. Bonding of transparent glass substrates 1a, 1b to each other.

[0039] The glass touch panel of this invention to be provided by the above manufacturing steps has ~~an~~ excellent high temperature and high humidity ~~proof~~ ~~owing~~ resistance due to the adhesive 6 being blended with hygroscopic fine particles, and ~~an~~ also has excellent smoothness ~~owing~~ due to the silver electrode 7 being blended with glass fibers, thereby realizing characteristics of freeness from screen distortion, image-quality unevenness, and interference ~~infringes~~ infringement, and also of ~~further of~~ extremely ~~less~~ little discoloration and aging change of a screen.

[0040] It is preferable that the adhesive 6 blended with the hygroscopic

fine particles is used as a thermosetting or room-temperature epoxy-type sealant, or a UV setting acrylic-type sealant. For ~~the~~ a thermosetting sealant, temporal baking is needed, and for ~~the~~ a UV setting sealant, UV irradiation is needed. As already described, the hygroscopic fine particles must ~~present~~ allow these sealants to exhibit high temperature and high humidity ~~proof~~ resistance ~~even~~ in these sealants while maintaining ~~the~~ an adhesive property ~~of these sealants~~.

[0041] Of course, the glass touch panel of Fig. 2, having ~~an~~ excellent high temperature and high humidity ~~proof~~ resistance, and ~~an~~ excellent smoothness, can be manufactured as well by ~~the~~ above steps 1, 2, 4, 5 and 6, excluding ~~the~~ step 3.

[Example]

[0042] A glass touch panel as shown in Fig.3 was actually manufactured ~~actually~~ by the following steps 1 to 6. ~~The main~~ Main dimensions ~~thereof~~ of the glass touch panel are ~~as the following~~ shown in Table 3.

Table 3
[Main dimensions of the panel]

Upper transparent glass substrate 1a:	0.2 mm thickness
Lower transparent glass substrate 1b:	1.1 mm thickness
Outer size:	140 × 85 mm
~~Operation~~ Operational area size:	130 × 59 mm

[0043] Step 1. Formation of ITO thin film

[0044] At first, transparent zinc borosilicate glass is adopted as ~~the~~ upper transparent glass substrate 1a and soda glass is adopted for ~~the~~ lower transparent glass substrate 1b, and ITO thin films having a film thickness of from 100 to 200 Å and a surface resistance of 500 Ω/□ (ohms per square) are formed as ~~the~~ transparent conductive films 2a, 2b by performing sputtering and CVD. ~~The~~

~~transparent~~ Transparent zinc borosilicate glass and ~~the~~ soda glass commercially available as ~~a substrate~~ substrates for a thin film were used.

[0045] Step 2. ITO patterning

[0046] Next, the following treatments are conducted sequentially ~~as~~ for ITO patterning.

・Pre-cleaning by applying supersonic waves

・Coating of resist ink by performing screen printing

・Baking at 120°C for 30 min.

・Etching of ITO with nitrate

・Peeling of the resist ink by using an alkali

・Post cleaning ~~using~~ by applying supersonic ~~wave~~ waves

[0047] Step 3. Formation of superfine particle dot ~~spacer~~ spacers 3

[0048] Next, the following treatments are conducted sequentially for ~~the~~ formation of superfine particle dot spacers.

・Coating of thermosetting resist-ink by printing with a metal mask

・Baking at 200°C for 60 min. so as to obtain a dot diameter of 20 μm, a dot thickness of 5 μm and a dot pitch of 3 mm~~.~~

[0049] Step 4. Formation of silver ~~electrode~~ electrode 7

[0050] Next, the following treatments are conducted sequentially ~~as~~ for formation of a silver ~~electrodes~~ electrode.

・Stirring of glass fiber in silver paste with a weight ratio of 1.2%

・Printing of the silver paste

・Baking at 180°C for about 60 min.

[0051] Step 5. Printing of thermosetting epoxy-type sealant as adhesive 6

[0052] Next, the following treatments are conducted ~~as~~ for printing of a thermosetting epoxy-type ~~sealants~~ sealant.

・Stirring of silica-type fine particles having a diameter of 10 μm ~~with~~ and a weight ratio of 2.5%

・Seal printing by using a thermosetting epoxy-type sealant

• Temporal Baking at 90°C for about 30 min.

[0053] Step 6. Bonding

[0054] As the final step, the upper transparent glass substrate 1a and the lower transparent glass substrate 1b are bonded together by performing the following procedures.

• Bonding by coating a minute amount of the silver paste onto contact points

• Setting ~~of~~ in a curing jig~~.~~

• Baking at 150°C for about 90 min. and ~~Cooling~~ cooling gradually

• Cutting

• Injection of air

• Sealing by UV adhesive

[0055] By performing the above manufacturing steps, a glass touch panel having the following performances and characteristics as shown in Table 4 was obtained.

Table 4
[Performances and Characteristics]

Driving system	Analog system
Writing method	Finger or pen
Light transmittance	85% (550nm)
Operation temperature	-30 to 65°C (90% RH or less)
Humidity ~~proof~~ resistance	1000 hours (60°C -95% RH)
Heat cycle	250 cycle (-30°C, +85°C)
Heat resistance	85°C
Operation load	80g
Surface Mohs hardness	6
Rating	0.8 mA (DC 5V)
Insulation resistance	12 MΩ (DC 25V)
Linearity	+ 2.0%
Bounce	8 msec

[0056] For comparison, a prior art glass touch panel was manufactured by ~~using~~ performing the steps disclosed in JP1997-146707, and its performances and characteristics are shown in Table 5. This prior art panel has the same outer

size and ~~operation~~ operational area size as the above panel of this invention, which are 140 × 85 mm and 130 × 59 mm, respectively.

Table 5 [Performances and Characteristics]	
Driving system	Analog system
Writing method	Finger or pen
Light transmittance	85% (550nm)
Operation temperature	-10 to 60°C (90% RH or less)
Humidity ~~proof~~ resistance	140 hours (60°C -95% RH)
Heat cycle	15 cycle (-30°C, +80°C)
Heat resistance	83°C
Operation load	100g
Surface Mohs hardness	6
Rating	0.8 mA (DC 5V)
Insulation resistance	12 MΩ (DC 25V)
Linearity	+ 3.0%
Bounce	8 msec

[0057] As is apparent from Tables 4 and 5, the glass touch panel of this invention ~~thus made~~ is ~~extremely~~ excellent in ~~the~~ terms of operation temperature, ~~the~~ humidity ~~proof~~ resistance, ~~the~~ heat cycle and ~~the~~ heat resistance as compared with the prior art glass touch panel. Consequently, a glass touch panel having an extremely improved environmental ~~proof (~~resistance~~)~~ is realized, and such panel is very ~~much~~ suitable to ~~the~~ an inner environment of a vehicle. It is ~~need less~~ needless to say that this panel is suitable not only for ~~the~~ inside ~~of the~~ a car, but also for various situations at high temperature and high humidity. Of course, the panel thus made is free from distortion, unevenness and interference fringes on ~~the~~ a screen, and ~~in the~~ exhibits good image quality.

[0058] As described above in detail, the invention can provide a novel glass

touch panel having ~~extremely~~ excellent characteristics ~~such as~~ in terms of durability, ~~operationability~~ operableness, freeness of ~~the~~ design and input accuracy, as well as being ~~extremely~~ excellent in terms of high temperature and high humidity resistance, and ~~in~~ also in terms of smoothness, as compared with ~~the~~ prior art glass touch panels.

ABSTRACT OF THE DISCLOSURE

~~This invention provides a~~ A novel glass touch panel ~~of extremely~~ is excellent in terms of high temperature and high humidity ~~proof, having~~ resistance, and has an upper transparent glass substrate 1a and a lower transparent glass substrate 1b bonded to each other by an adhesive 6~~,~~ having hygroscopic fine particles mixed ~~thereto~~ therein.

APPENDIX A

CONSIDERATIONS IN SELECTING PARTICLE SIZE CUT POINT FOR FINE PARTICLES

An important decision relating to the choice of indicator is the choice of measurement which in a sense serves as an operational definition of fine particles. The CD concludes that the minimum of mass between the fine and coarse modes lies between 1 and 3 μm, and that the scientific data support a cut point to delineate fine particles in this range (CD, Chapter 3-5). Because of the overlap of fine and coarse particles in this intermodal region, specific cut points are only an approximation of fine particles. Thus, the decision within this range is largely a policy judgement. Although most fine particle (accumulation mode) mass is below 1.0μm, some hygroscopic particles in conditions of high relative humidity may gain water and grow above this size. However, energy considerations normally limit coarse mode particle sizes to greater than 1.0 μm in diameter (CD, 3.1.2).

The main policy choice centers on two options: $PM_{2.5}$ and PM_1. Staff recommend the three primary factors to consider in selecting a cut point are consistency with health data, potential for intrusion of mass from the other mode, and availability of monitoring technology.

From a public health perspective, use of a $PM_{2.5}$ cutpoint will result in the capture of all of the potential agents of concern in the fine fraction. For example, the cutpoint of $PM_{2.5}$ captures most sulfates, acids, fine particle metals, organics, and ultrafine particles and accounts for most of surface area, and particle number. Although the CD outlines some conditions (e.g., relative humidity near 100 percent) under which it is possible that hygroscopic particles may grow above 2.5μm, use of the $PM_{2.5}$ cutpoint is still better at capturing the constituents of concern than PM_1.

$PM_{2.5}$ has been measured directly in many health studies as described in the CD and Chapter V, Section F above. Significant associations have been reported between $PM_{2.5}$ concentrations and mortality, hospital admissions, cough, upper respiratory infection, lower respiratory infection, asthma status, and pulmonary function changes.

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$PM_{2.5}$ measurement technologies are widely available and have been in routine use in the field since the early 1980s. For example, the EPA AIRS database contains $PM_{2.5}$ data from the Inhalable Particle Network (1982-1984), the IMPROVE network (1987 - present), and the NESCAUM network (1988- present). In addition, the California Air Resource Board (CARB) dichotomous sampler network has been collecting $PM_{2.5}$ data routinely since 1980, and many other special studies measuring $PM_{2.5}$ have been conducted across the country. Furthermore, dichotomous samplers allow the coincident measurement of PM_{10} and $PM_{2.5}$, increasing the certainty of comparability between the two measurements.

Measurement of fine particle mass using a 1 μm (PM_1), on the other hand, has not been used in health studies primarily due to lack of available monitoring data. Comparisons between PM_1 and other measurements that were used in the health studies (e.g., PM_{10}) are also not widely available due to lack of available PM_1 monitoring data. Furthermore, PM_1 may not capture as much of the hygroscopic substances such as sulfates which health studies report as having statistically significant associations between sulfate measurements and endpoints including increased mortality and hospital admissions.

PM_1 sampling technologies have been developed and some limited validated data are available from locations such as Phoenix, Arizona. However, the PM_1 samplers have not been widely field-tested to date.

Proponents of the PM_1 option are concerned that the intrusion of particles generated by grinding or crushing (i.e., coarse mode particles) into the daily $PM_{2.5}$ measurement could create spurious NAAQS exceedances. Given the lack of PM_1 data currently available, it is difficult to determine how much intrusion might occur or what areas might be affected during the implementation of a $PM_{2.5}$ NAAQS. The available data show that typically only 5-15 percent (on the order of 1 to 5 $\mu g/m^3$) of the $PM_{2.5}$ mass is attributable to soil-type sources even in dusty areas such as San Joaquin Valley, California, and Phoenix, Arizona. However, this percentage may increase during events such as high winds.

The staff judges that in typical urban areas, the potential for this type of intrusion may be smaller, but without sufficient data these determinations remain very uncertain. A sharper inlet for the Federal Reference Method may help to minimize the intrusion of coarse mode

particles into the $PM_{2.5}$ measurement. Although intrusion of coarse mode particles into daily $PM_{2.5}$ measurements is not anticipated to be significant in most situations, if in light of more data a problem is identified, this issue might be better addressed on a case-by-case basis in the monitoring and implementation programs.

Finally, the staff concludes that $PM_{2.5}$ measurements are more appropriate than some of the measurements historically used in the epidemiological studies (e.g., BS, CoH) although these measurements have been useful in advancing the state of scientific knowledge of particle effects. British Smoke (BS) readings vary more with darkness of particles (i.e., carbon content) than with mass, making associations with mass highly site- and time-specific. The BS method emphasizes control of primary elemental carbon emissions; however, elemental carbon is a minor contributor to fine and total mass in current U.S. atmospheres. Furthermore, lack of consistent relationships between BS reflectance and PM mass measurements diminishes one of the major advantages: BS is not related to the available quantitative health data from U.S. cities with as much certainty as the $PM_{2.5}$ mass measurements although BS is used in many other countries. Using a similar principle to BS, the principle of coefficient of haze (COH) is that visible light is transmitted through (or reflected from as in the case of BS) a section of filter paper before and after ambient air is drawn through it. Thus, COH associations with mass are also highly site- and time-specific.

Thus, because of the consistency with health data, small potential for intrusion, and availability of monitoring technology and existing air quality database, the staff judges that the $PM_{2.5}$ measurement is more appropriate for regulatory purposes than PM_1, or historical measurements such as BS or COH.

APPENDIX B

MEASUREMENT METHODS FROM EPIDEMIOLOGY STUDIES

The CD and Chapter V of this Staff Paper summarize health studies which have reported associations between various indicators of PM and health effects. The main mass concentration indicators are TSP, PM_{10}, and $PM_{2.5}$. In addition to $PM_{2.5}$ mass measurements, fine particles have been measured in the U.S. and abroad using a variety of techniques including British or black smoke (BS), coefficient of haze (COH), carbonaceous material (KM), and estimates from visibility measurements (CD, Section 4.2.8).

Studies have also reported associations between health effects and exposure to fractions found predominantly in the fine fraction such as sulfate ($SO_4^=$) and strong acidity (H+). The CD describes measurement techniques in detail; this section highlights relevant information about other indicators of fine particles (i.e., BS, COH, and KM).

In the past, it was noted that visibly black plumes were emitted by industrial sources; thus, light absorption was adopted as a measure of PM pollution (Chow, 1995). Measurements of the optical properties of particles may be related to gravimetric mass measurements on a site- and time-specific basis with on-site calibrations.

BS preferentially measures elemental carbon particles found in the fine fraction (CD, Section 4.2.8; Baily and Clayton 1980). In addition, the BS inlet design, taken together with its other operating parameters, restricts the size of particles that are sampled. For example, it has been shown in wind tunnel tests that the best estimate of the cut point for BS is 4.5 μm (CD, page 4-52; Waller, 1980; McFarland, 1979). Most particles larger than the cut point of 4.5 μm are either rejected at the inlet or lost in the inlet line (U.S. EPA, 1982a). Furthermore, the BS reading varies more with darkness of particles (i.e., carbon content) than with mass, thus making associations with mass highly case-specific. Because elemental carbon is found predominantly in the fine mass (less than 1.0 μm range), variations in BS are more closely related to fine mass and unlikely to be sensitive to coarse mode particles (NAS, 1980; U.S. EPA, 1982b).

Using a similar principle to BS, COH measures visible light transmitted through (compared to reflected from in the case of BS) a section of filter paper before and after

ambient air is drawn through it. The amount of light transmitted is measured by a photocell (Chow, 1995; Fairley, 1990). In addition, this sampler uses a funnel inlet and a small diameter transport tube nearly identical to the BS sampler. Although the two samplers operate at different flow rates, the particles reaching the filter tape could be expected to have a size range similar to that of the BS instrument (U.S. EPA, 1982a, see Figure 3A-12).

Prior to the 1980s, PM was measured in California by optical reflectance of particles collected on a sample tape (KM). Similar in principle to BS, KM has been shown to be closely related to elemental carbon content in Los Angeles (Kinney and Özkaynak, 1990). Similar to BS, KM is also a fine particle measurement.

Visibility measurements can also be used as a reasonable surrogate to estimate fine particle concentrations because the extinction coefficient is directly related to fine particle mass (CD, page 6-216).

APPENDIX C

PM_{10} NATIONAL CONCENTRATION MAPS AND DEFINITIONS OF REGIONS

Current U.S. PM_{10} levels are illustrated in Figures C-1 and C-2. Figure C-1 shows the fourth highest 24-hour PM_{10} concentration recorded in a county and Figure C-2 depicts highest annual mean PM_{10} concentration using 1992 to 1994 AIRS data in each county for which data completeness criteria were met. Counties not represented with a monitor are left blank.

The following methods were used to calculate the values depicted in the maps. The current single exceedance form of the PM_{10} daily standard allows for an average of one exceedance per year over a three-year period. Thus, the fourth highest concentration is of interest because this value is used to determine attainment with the current daily standard. Seven hundred and twelve counties met the data completeness criterion of at least 75 percent complete data for the period 1992 to 1994. For these counties, all daily concentrations were ordered largest to smallest and the fourth highest PM_{10} concentration was determined for each site. If a county had only one site, then the fourth highest concentration for that site was reported. If a county had more than one site, the site with the maximum fourth highest concentration was used to represent the county.

Figure C-2 shows the maximum annual mean concentration in each county over the three-year period using an average weighted by calendar quarter. Three hundred and eighty counties met the 75 percent data completeness criterion by quarter for 1992 to 1994. Means were calculated for all four calendar quarters for each year in the 3-year period and annual values were calculated based on the quarterly means. The three yearly means were then averaged to obtain one value for each site. If a county had only one site, then the annual mean for that site was reported. If a county had more than one site, the site with the maximum annual mean was used to represent the county.

Figure C-3 shows the regions of the country used in some air quality analyses. Note that state boundaries were used except that California and Texas were split.

Figure C-4 illustrates that a total of 87 different sites reported $PM_{2.5}$ data to AIRS from 1983 to 1993. Over the 11 year period, less than 50 sites reported data to AIRS in any given year. Additional special studies have also monitored $PM_{2.5}$, but these data are not reported in AIRS.

Figure C-1.

Figure C-2.

Figure C-3. Regions Used in Air Quality Analyses in this Staff Paper